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"For Business and Industry"

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LOW EMISSIVITY CEILINGS

The Facts...

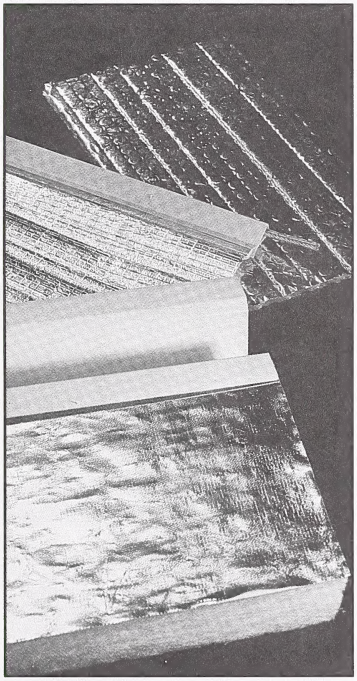
Many community groups operating public artificial ice surfaces in Alberta are answering the high energy costs of operating their ice plants with a variety of new technologies. One of these new technologies is the low emissivity (ε) ceiling.

Low-ε ceilings have been installed in a number of arenas and curling rinks in the province in the past few years. Installing a low-ε ceiling simply means placing a highly reflective surface at or near the ceiling.

Indoor ice rinks create a unique condition where a cold ice sheet is maintained beneath a warm ceiling. The ceiling is warmed by infrared solar radiation, by outside air, and by air stratification within the building. In turn, the ice sheet is warmed by infrared heat re-radiated from the ceiling. This ceiling radiant heat load is one of the largest sources of heat to be removed by an ice plant in an indoor ice rink (see Table 1).

Emissivity refers to the property of a material as a radiator of infrared heat. A material that radiates no heat has an emissivity of zero; a perfect radiator has an emissivity of one. Most structural and ceiling materials have a emissivity of about 0.90, such that they radiate 90% of their heat energy to the ice. Special aluminum paint can lower the emissivity to about 0.40. Polished metals can lower the emissivity to 0.05 or lower. Thus, a low emissivity ceiling can significantly reduce radiant heat transfer.

Although many polished metals have a low emissivity, cost, ease of handling, and other considerations have favoured the use of aluminum foils. Several manufacturers have produced products with aluminum foil laminated to various backing materials. Typically, the products either serve as an air vapour barrier, often laminated to insulation, or purely as a radiant heat shield. Backing materials include kraft paper, polyethylene or vinyl sheeting, or polyethylene bubble-pack. Where the product acts as a vapour barrier, it is installed next to the ceiling; if only as a radiant heat shield, it is suspended below the ceiling. Product and installation costs vary considerably.



Examples of low emissivity ceiling products.

Applying these materials can have some important benefits. Condensation and fog can often be reduced. Increased reflectivity generally improves light levels, possibly allowing changes to light fixtures which could further reduce costs. Acoustical improvements are sometimes noted. Lower operating hours should increase the operating life of the ice-plant equipment and reduce maintenance costs.

The Application...

Medicine Hat Arena is home to the Medicine Hat Tigers of the Western Canada Hockey League. Built in 1970, the building area is 66,260 square feet comprising a 17,000 square foot ice surface sur-

The Energy Bus visits the Medicine Hat Arena.

rounded by spectator seating, a large lobby area, concession, offices, dressing rooms, maintenance, and storage areas. Due to summer hockey and figure skating schools, the ice surface is typically maintained for 11 months of the year.

In late 1985, an energy audit of the complex was conducted by the Alberta Energy Bus Audit program. During the audit, the idea of using a low emissivity ceiling over the ice surface was estimated at $5,839 in electrical savings per year. Around the same time, the Medicine Hat Arena was approached as a possible technology demonstration site for low emissivity ceilings under an Alberta/Canada Energy Resources Research Fund (A/CERRF) program.

At Medicine Hat the low-Ɛ ceiling was installed just below the upper member of the roof trusses

The Medicine Hat Arena was selected for the A/CERRF study and in May 1986 a low emissivity ceiling was suspended just below the upper member of the metal roof trusses. The installed cost was $29,500. The payback period (installed cost divided by expected energy savings) was estimated at about 5 years, based on an electrical energy savings rate of about 3 cents per kilowatt • hour (kW • h).

Compressor operating time fell from 9,441 hours in the 1985/86 season to 6,838 hours the following year, a saving of 2,603 hours. 1990 records are consistent, showing 6,470 hours of operating time.

At the end of the A/CERRF study (1988), a revised payback of 8.3 years was calculated. However, by 1992 the savings rate had increased to about 3.5 cents per kW • h, which shortens the payback period to less than 8 years.

One explanation of the long payback period is that Medicine Hat enjoys some of the lowest energy costs in the province. For comparison, a similar installation in Edmonton was evaluated at a 1.9 year payback, at the time of the A/CERRF study. The difference was attributed to a slightly lower initial cost, a greater reduction in compressor hours, and a 6.1 cent kW • h savings rate (twice that of Medicine Hat).

At yet another installation in the Centennial Arena in Lac La Biche, a payback period of 5.2 years was calculated.

Clearly, initial capital cost and the energy savings rate are two of the most important factors which must be considered in an economic evaluation of this technology.

Table 1: Ice Rink Heat Loads, Indoor Rinks

Load Source	Approx. Max. Percentage of Total Load, %	Max. Reduction Through Design and Operation, %
Conductive loads:		
Ice resurfacing	12	60
System pump work	15	60
Ground head	4	80
Sender heat gain	2	40
Skaters	4	0
Convective loads:		
Rink air temperature	13	50
Rink humidity	15	40
Radiant loads		
Ceiling radiation	28	80
Lighting radiation	7	40
Total	70	

Extracted from and reprinted with permission by the American Society of Heating, Refrigerating and Air-Conditioning Engineers from the 1980 ASHRAE *Handbook – Refrigeration.*

The Bottom Line...

The following illustrates the potential of a low-$\mathcal{E}$ ceiling. The procedure can be used to roughly approximate the radiant heat flow between two surfaces, and the potential savings available.

Generally, the end effect of the installation of a low-$\mathcal{E}$ ceiling is a reduction in compressor operating hours. Less refrigeration load equals less hours.

For this example, consider an arena with the following characteristics:

- rink dimensions = 200' x 85' = 17000 ft^2 (1580 m^2).
- ceiling height = 30' (9.1 m^2).
- ice temperature = 20 °F (-6.7 °C) average.
- ceiling temperature = 60 °F (15.5 °C) average.
- 4000 compressor operating hours.
- 50 tons refrigeration (175.8 kW).
- 85 horsepower (63.4 kW) total.

A suspended low -$\mathcal{E}$ ceiling will normally cause the average ceiling temperature above the radiant barrier to rise, usually 10 - 20 °F (5.5 - 11.1 °C). This effect would not occur with radiant barriers placed against the ceiling. Here, no increase in ceiling temperature is assumed.

Table 2 Low-$\mathcal{E}$ Ceiling Radiant Heat Transfer Rates

Ice/Ceiling Average Temperature Difference	Heat Transfer Rate Btu/hr*ft^2 (W.m^2)
25°F (13.9°C)	1.03 (3.24)
30°F (16.7°C)	1.25 (3.95)
35°F (19.4°C)	1.48 (4.68)
40°F (22.2°C)	1.72 (5.43)
45°F (25.0°C)	1.97 (6.21)
50°F (27.8°C)	2.22 (7.00)
55°F (30.6°C)	2.48 (7.82)

Figure 1

Configuration Factors for Curling Rinks and Arenas

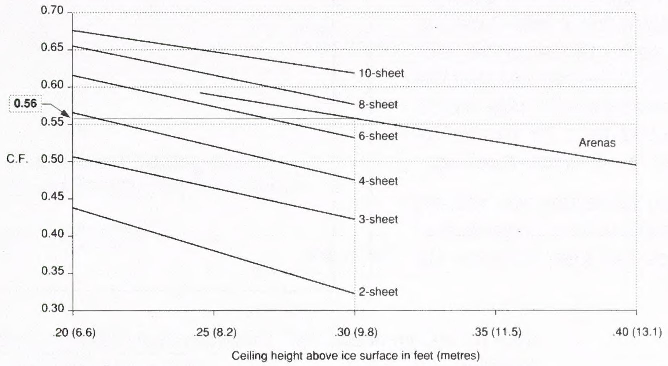
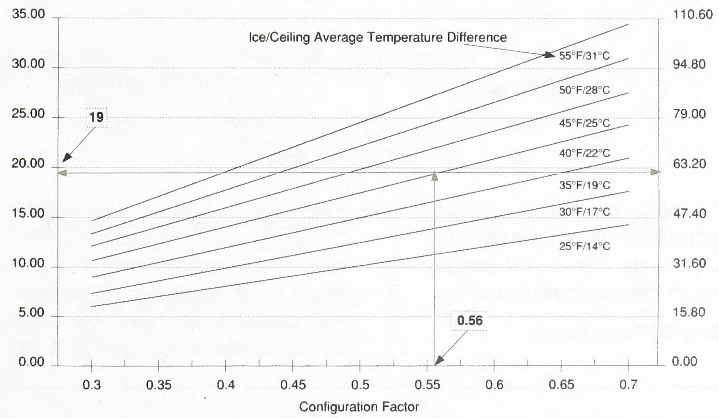


Figure 2

Radiant Heat Transfer Rates



*To convert from Btu/h*ft² to W/m², multiply by 3.1546*

First, calculate the coefficient of performance (COP) of the ice plant. This is simply the ratio of plant output to plant input, or, heat removed by the system versus the work required to run the compressors and auxiliary equipment (fans, pumps, etc.). One equation which can be used for this is:

$$\text{COP} = \frac{\text{Tons of refrigeration x 12,000 Btu/ton}}{\text{Total horsepower x 2,544 Btu/hp}} = \frac{50 \times 12000}{85 \times 2{,}544} = 2.77$$

or,

$$\text{COP} = \frac{\text{Output kW}}{\text{Input kW}} = \frac{175.8}{63.4} = 2.77$$

Next, determine the radiant heat transfer rates. A configuration factor is used to take into account the emissivity of both surfaces (the ceiling and the ice) and the fact that not all of the radiated energy from one surface will fall on the other. The existing ceiling emissivity is assumed to be 0.90, which is typical for most building materials. The emissivity of ice is usually considered to be 0.95.

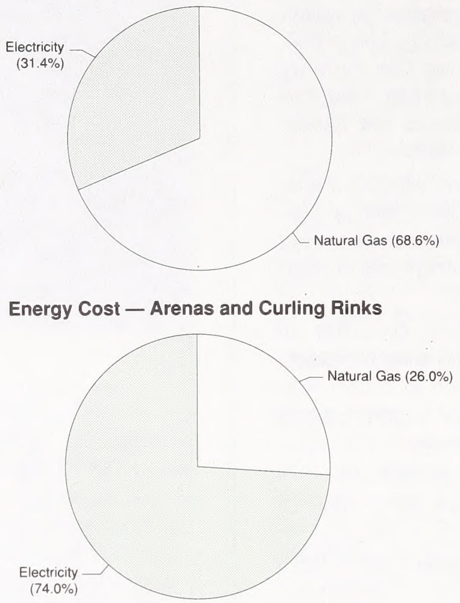
From figure 1 we obtain a configuration factor of about 0.56 for a 30 foot ceiling (for peaked or arched ceilings use an average height).

From figure 2 we find the radiant heat transfer rate to be about 19 Btu/hr*ft^2(60 W/m^2) for a configuration factor of 0.56.

For most purposes, the configuration factor for a low-$\mathcal{E}$ ceiling can be considered to be .05. From table 2, we can see that the radiant heat transfer rate would be reduced to 1.72 Btu/hr*ft^2 (5.43 W/m^2) with a low-$\mathcal{E}$ ceiling.

Once you have the two radiant heat transfer values, existing and low-$\mathcal{E}$, you can then estimate the savings:

Figure 3



Energy Use — Arenas and Curling Rinks

Energy Cost — Arenas and Curling Rinks

$$\text{kW}\cdot\text{h Savings} = \frac{(\text{Current Btu/hr*ft}^2 - \text{Proposed Btu/hr*ft}^2) \times \text{Ice Area (ft}^2) \times \text{Compressor Hours}}{\text{COP} \times 3{,}413\ \text{Btu/kWH}}$$

$$= \frac{(19 - 1.72) \times 17{,}000 \times 4{,}000}{(2.77 \times 3{,}413)} \approx 124{,}300\ \text{kW}\cdot\text{h}$$

or,

$$\text{kW}\cdot\text{h Savings} = \frac{(\text{Current W/m}^2 - \text{Proposed W/m}^2) \times \text{Ice Area (m}^2) \times \text{Compressor Hours}}{\text{COP} \times 1{,}000\ \text{W/kW}}$$

$$= \frac{(60 - 5.43) \times 1{,}580 \times 4{,}000}{(2.77 \times 1{,}000)} \approx 124{,}300\ \text{kW}\cdot\text{h}$$

Finally, determine your savings rate per kW.h. At a savings rate of 3.5 cents per kW • h, the annual savings in this example would be:

124,300 x \$0.035 = \$4,350

Your utility company can explain the charges on a typical winter month bill. You will find that your monthly bill is separated into several blocks of charges, with each of these blocks charged at a different rate (cents per kW • h). Your savings rate will come from the lowest rate at which you are charged, in the last block of charges.

SECTOR REVIEW

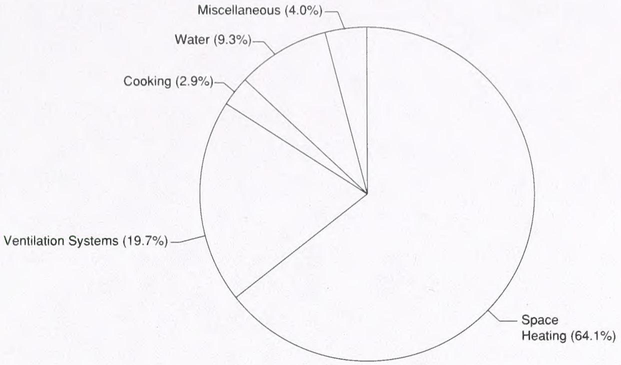
Energy Use and Savings Potential in Arenas and Curling Rinks...

In Alberta, according to a 1992 Alberta Parks and Recreation survey, there are 322 curling rinks (1180 ice sheets), and 386 arenas, located in 568 facilities around the province. As of September 1992, the Alberta Energy Bus program had conducted energy audits at 74 (13%) of these facilities.

An energy audit identifies where energy is being used and how

Figure 4

Arenas and Curling Rinks
Natural Gas Energy Use Breakdown



Arenas and Curling Rinks
Electrical Energy Use Breakdown

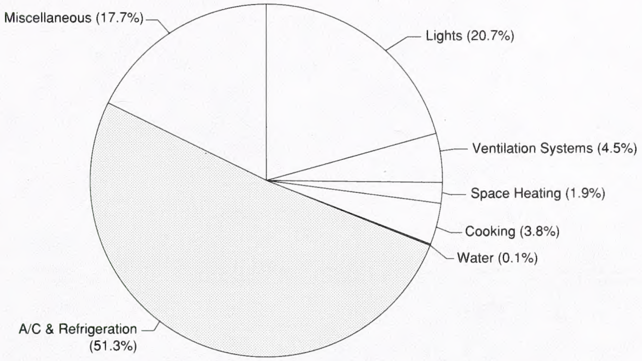
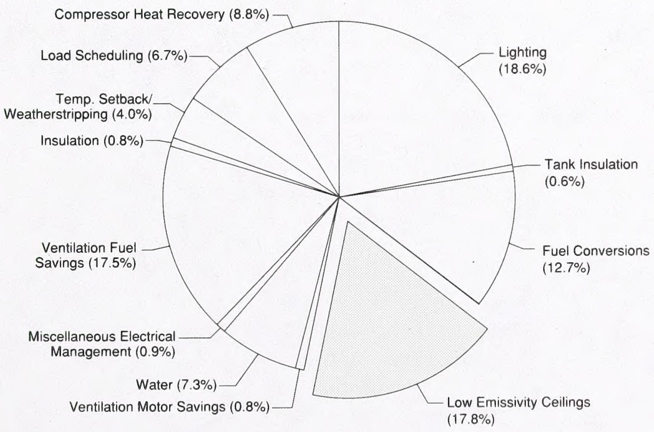


Figure 5

Low Emissivity Ceiling Saving Potential
As Recommended in 8 Facilities



much it costs in each area. Energy efficiency measures are then suggested which may result in energy cost savings.

Figure 3 compares the average energy use and energy cost for these facilities. Electrical energy use per facility averaged about 460,000 kW • h, costing $25,700. Natural gas use averaged 3,600 gigajoules (GJ), at $9,000. Total costs, therefore, are about $34,700 per facility.

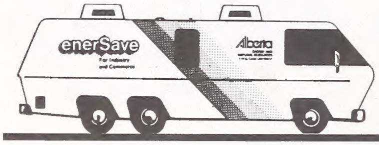
Figure 4 shows where energy is typically being used in arenas and curling rinks. The dominant form of natural gas use is in building heating and ventilation, with small amounts being used for concessions, water heating (domestic and flood), and miscellaneous uses such as pilot lights, snow melt systems, etc. Similarly, electrical energy use is dominated by one item, refrigeration needs, with lighting, concessions, ventilation fan motors and miscellaneous uses (combined) consuming slightly less than one-half.

Figure 5 identifies the potential for savings of low emissivity ceilings. To date, a low-$\mathcal{E}$ ceiling has been recommended in 8 facilities. Summarizing these savings shows average potential cost reductions of about $4,200 per facility.

From the variety of areas in which savings have been recommended, it is clear that looking closely at arena and curling rink operations can reveal many opportunities for energy and cost savings.

FOR MORE INFORMATION

The article *Low Emissivity Ceilings* was researched by Shaun Martin. The Energy Efficiency Branch gratefully acknowledges editorial reviews done by Mr. John Bokstein of the City of Medicine Hat, and Mr. Wayne Page of Alberta Tourism Parks and Recreation. For detailed information on energy cost-saving calculations and the energy audit database, contact the technical services section of the Energy Efficiency Branch: Phone 427-5200 (collect).



ENERGY $AVER$

Energy $aver$ is a series of fact sheets about energy efficiency measures that have wide application in Alberta. Each issue highlights a different technology and its successful use in the province. The Sector Review summarizes energy use patterns of different facilities that have used Alberta's Energy Bus audit service. Comments, questions and suggestions are welcome.

Write or phone (collect) to be placed on the mailing list. You may also receive back issues or arrange for an Energy Bus audit (conducted at no charge).

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